Reviews.

The Great Ice Age. By Professor James Geikie. Third edition. London: Edward Stanford, 1894, pp. xxviii + 850. xvii plates.

The progress of glacial geology has been so great during the last few years that a new edition of this classic work is most welcome. Much the larger part of the volume has been rewritten. Even those parts which are only revised are so modified that they read as if now written for the first time. Apart from the alterations which the studies of recent years have made necessary, the general scope of the volume is somewhat changed. In the present edition, the glacial phenomena of the continent of Europe have received much fuller and much more systematic treatment than in the preceding. The glacial phenomena of Asia, Africa, Australia and South America also come in for their share of attention. The chapters which deal with the glacial phenomena of North America (52 pages) were contributed by Professor Chamberlin, and suggest much that is new in the way of classification and correlation. Another important change is the transfer of the discussion of the causes of the glacial period to the end of the volume. This arrangement seems to make this chapter much less than heretofore an organic part of the volume, and it is distinctly pointed out that the general facts and relations set forth in the rest of the volume are not dependent on any particular theory of glacial climate. Many of the minor changes of the volume are significant, and not the least point of significance is the fact that they are very generally brought into harmony with the results of recent research in our own country.

By way of illustration it may be mentioned that kames and åsar are now sharply distinguished from each other, and that the discussion concerning their origin is somewhat changed. It is interesting to note that Professor Geikie believes the åsar to be, for the most part, the products of subglacial, not of superglacial streams. In connection with kames some interesting facts concerning their distribution and relations are indicated. In Scotland they are said to be especially abundant "oppo-

site the mouths of our larger valleys." Quoting Mr. Jamieson, Professor Geikie points out that kames are often grouped in belts which "lie across valleys in long sinuous lines, forming curves or segments of a circle, the concavity of which is presented to the head of the valley, and their convexity toward the sea or downward end, as in terminal moraines." Outside these belts and groups of kames, there are frequently found wide flats of gravel and sand, sustaining the same relation to the kame-belts that similar deposits sustain to moraines, and, more rarely, to belts of kames in our own country. Professor Geikie does not fail to note the close relationship between certain aggregations of kames and terminal moraines. It was just this moraine-like habit of certain kame belts, moraine-like both in themselves and in their relations, which led the writer to propose for them the name *kame-moraines.*[1]

Apropos of the question which has been raised, on this side of the water, as to the reality of the existence of rock basins produced by glacier erosion, it may be noted that Professor Geikie asserts that the "largest and most important lakes of Scotland" as well as a "vast number of mountain tarns" lie in rock basins. There is no hesitation in ascribing these rock basins to the work of glacier ice.

Important as many of the minor changes in the new edition are, the chiefest interest is likely to centre in the discussion concerning the succession of glacial epochs. In Scotland Professor Geikie finds what he regards as evidence of five glacial epochs. In England the Weybourn and Chillesford crags are believed to represent the deposits of a still earlier epoch when the climate was arctic in Britain, and when considerable glaciers were in existence, though the crag deposits themselves are not looked upon as the direct product of ice. These crag deposits, together with the overlying Cromer forest beds, are referred to the Pliocene. According to this interpretation, the beginning of the glacial period is not coincident with the beginning of the Pleistocene.

Instructive maps are given, showing the extent to which the ice covered Great Britain and Ireland, and the continent as well, in the second, third, and fourth glacial epochs. During the second epoch, Ireland, Scotland, and Wales were completely covered by ice, and glaciation extended essentially to the valley of the Thames. On the continent the ice is represented as having extended so far south as to cover

[1] Annual Report of the State Geologist of New Jersey, 1892, page 93.

all of Holland and part of Belgium. In Germany it extended to the Erz and Carpathian Mountains. It reached its southernmost extension in the valley of the Dneiper, somewhat below latitude 50°. A further point of interest is the representation of an independent ice sheet of considerable extent in northeastern Russia and the adjacent parts of Asia, about the Timan and Ural Mountains. The ice sheet which centred here is mapped as extending westward until it came in contact with the ice sheet which spread eastward from Scandinavia. This subordinate ice sheet had an area about as great as that of France. According to the map, the edge of the ice during this epoch was markedly lobate, especially to the eastward. Expression is also given to the idea that some of the mountain ridges well within the area of the *mer de glace* exerted, even at the time of maximum glaciation, a considerable influence on the direction of ice movement. The mountains of Great Britain, of Ireland, and of Eastern Scandinavia are represented as having never been so deeply covered with ice but that they continued to exert an influence upon the direction of its movement. They served as local centres of glaciation while the ice sheet was developing, and as such would seem never to have altogether lost their identity.

During the next glacial epoch (the third) ice again covered all of Scotland, but failed to override the southern extremity of Ireland. It left a considerable part of Wales uncovered, and encroached upon the borders of England only at the north, northwest, and northeast. On the continent, the ice failed to reach its earlier limit. Hamburg, Berlin, and Warsaw lie near the limit of its advance, and there was no independent ice sheet in the region of the Urals. The Scandinavian and British ice sheets were again confluent. During the fourth epoch, glacier-ice in Britain was largely confined to the mountain valleys of Scotland, though the valley glaciers sometimes came down so as to coalesce on the low lands, making somewhat extensive "district" or piedmont glaciers. On the continent, the ice covered the eastern half of Denmark, and reached southward to the Baltic ridge. It failed to cover all the southern part of Sweden, and did not encroach far upon Russian soil. The British and Scandinavian ice sheets were not confluent. During the fifth and sixth epochs, the development of ice was still more restricted, the glaciers of the last being less extensive than those of the fifth.

What is the basis on which the subdivision of the glacial period is

based? There would seem to be no question as to the distinctness of the Weybourn crag from the oldest glacial formations of the British Isles. The only question would seem to be concerning the glacial character of the Weybourn crag epoch. In favor of this view Professor Geikie seems to make a strong case. Between the drift of the second and third glacial epochs, the "lower" and "upper" bowlder clays of England, there seems to be a well marked interglacial horizon. This horizon represents an interval during which the land surface of Britain was considerably elevated. During the time of elevation the climate changed from arctic to temperate, and the land surface became well clothed with vegetation, and was occupied by man and Pleistocene mammalia. Following this condition of elevation, there was submergence of the land to an undetermined extent. During the submergence the climate changed from cold-temperate to arctic. The increase in the severity of climate accompanying the submergence resulted in a second *mer de glace*. Thus a very considerable period of time, accompanied by a very considerable amelioration of climate, and by very considerable changes of level, separated the lower drift of Britain from the upper.

The evidence on the basis of which the third epoch represented in Scotland (the fourth of the full series) is separated from the preceding, is drawn from several sources. (1) The mountain valley lake basins are believed to represent the work of advancing ice, not the work of the receding ice (valley glaciers) of the third epoch. (2) The bowlder clay in the mountain valleys possesses a topography which is fresher (less eroded) than that of the bowlder clay of the surrounding country. (3) Above the valley moraines which are thought to mark the termini of the glaciers of this epoch, there is an absence of till in the bottoms ot the valleys, and on their lower slopes. Higher up the slopes bowlder clay is present, as also in the same valleys below the moraines. The absence of bowlder clay in the situations specified is attributed to the erosive work of the mountain glaciers of the third (Scotland) epoch. (4) The moutonnées, striæ, etc., in the areas thought to have been covered by the local glaciers of the third epoch are fresher than the corresponding features elsewhere. (5) The coincidence of direction of ice movement with the courses of the valleys in the third epoch is striking, while during the preceding epoch the direction of ice movement was independent of topography. (6) It is thought that after the last great ice sheet (that of the third ice epoch) withdrew from Scotland, there

were considerable changes of level, before the ice of the next epoch reached its greatest development.

The evidence brought forward along these lines in support of the separation of the epoch of the "district" glaciers of Scotland from the epoch of the preceding *mer de glace* is such as to make it clear that the former was in some measure distinct from the latter. The ice of the so-called fourth epoch would seem to mark a distinct stage in glacial history, a stage when the ice was more active than for a time preceding. But the evidence is not such as to make it clear that the epoch of "district" glaciers was so far separated from the last *mer de glace* of Scotland as to entitle it to the rank of a separate epoch, as that term is used in America. If local glaciers of the dissolving ice sheet tarried long in the mountain valleys, their persistence would seem to explain some of the phenomena cited as evidence of the separation of the epochs. A temporary and relatively slight re-advance of such glaciers during the general dissolution of the ice sheet might bring them again into vigorous action. Such recrudescence would at least help to explain such phenomena as call for advancing ice. The coincidence of the direction of striæ in the mountain valleys with the slopes of the surface, and the independence of striæ with reference to slopes elsewhere, does not seem to the writer strong evidence of an independent ice epoch during which the ice was largely confined to the valleys. It is believed that existing striæ were very often, if not very generally, made by the later phases of ice movement in the regions where they occur. It seems rational to believe that while Scotland was covered with ice to great depths, the movement of the same was largely independent of topography; but that later, when the ice was undergoing dissolution, when the highlands had become bare, and when the valleys were still occupied by ice, its motion was in correspondence with the local slopes. Such striæ as were developed at that time would necessarily be in harmony with the direction of the valleys. It is believed that a re-advance might take place sufficient in vigor to explain the phenomena cited from Scotland, without being of sufficient extent, or of sufficient importance from other points of view, to be regarded as a distinct glacial epoch. If, on the strength of the evidence presented, we are not altogether convinced that the third glacial epoch represented in Scotland (the fourth of the full series) was sufficiently distinct from its predecessor to be ranked as a distinct epoch, as we have been accustomed to use that term, it does not follow that new evidence may not yet

lead to this conclusion. If the fourth epoch of Professor Geikie be no more than an episode, as terms are used in America, the recognition of its proper measure of distinctness is still important. An episode may ultimately come to possess a significance scarcely less than that of an epoch. Even if the "district" glaciers represented but a very moderate re-advance of the ice, this re-advance is worthy of differentiation since it helps to emphasize the general fact of the complexity of the glacial period as a whole.

When we come to the separation of the fifth from the fourth glacial epoch, and of the sixth from the fifth, it must be confessed that the evidence presented is very far from convincing, if the word epoch is to retain the meaning which has been attached to it in this country. From the written page it does not appear that the so-called fifth and sixth glacial epochs of Scotland necessarily amount to more than considerable recrudescences of glaciers which were previously retreating. But even if these recrudescences be of minor extent only, they should be recognized for what they are. If they be not separate epochs, in our sense of the term, there can be no doubt that they represent more or less distinct advances of the ice, and their separate recognition helps to emphasize what seems to be the fact in America as well as in Europe, viz., that the glacial period was long and complex. To this conclusion detailed work on both continents seems to be surely leading.

The drift of Southern England, "rubble drift," "head," etc., is ascribed to torrents connected in time with the ice epoch. The material, if we understand Professor Geikie rightly, is not for the most part material that was worked over by the ice, but rather the product of rock disintegration in cold climates. It is believed that the frozen surface outside the ice prevented the penetration of the rain water. Under these conditions, precipitation and drainage might give rise, especially in the warmer seasons, to considerable floods. Such waters, it is believed, bore the rubble from its native place and spread it upon the plains to the south. If this interpretation be correct, it may have an important bearing on gravel deposits outside the glacial drift in other countries.

On the continent, "upper" and "lower" series of drift deposits are recognized on all hands. There are numerous beds which have been more or less generally classed as interglacial. They are found at intervals over a stretch of country extending from the North Sea to Moscow. Many of the continental geologists have been in the habit of putting them together, and of regarding them as the great division plane between the "upper" and "lower" tills. Independently of the inter-

glacial beds, an "upper" till is sometimes seen to be distinctly unconformable on a "lower," the relations being such as to indicate that the lower was exposed for considerable periods, and subject to extensive erosion, before the upper was deposited on it. This relationship does not necessarily indicate great recession of the ice between the times of deposition of two bodies of till. So far as the physical relations are concerned, the upper body of till might be the work of an advancing ice sheet which had previously retreated but a short distance, but which remained long in retreat.

It is surely most significant that the same general conclusions concerning the multiplicity of ice epochs are reached, whatever part of the continent be examined, provided it be within the glaciated area. Thus in Northern Norway, after an epoch of glaciation there appears to have been an epoch of submergence until the sea stood 63 meters higher than now. Then the land rose so that the sea stood about 35 meters higher than now. Then followed another epoch of glaciation. Between the deposits of these glaciations there are marine beds containing fossils. In Southern Sweden there are non-glacial fossil-bearing beds overlain and underlain by ice deposits. In Schleswig and the Danish Islands there are similar beds in similar relations. Of the eighteen species found in these beds, eleven have a southern range, four have a wide range north and south, while three species only are distinctly northern. Again in Eastern Holstein, and on the islands of Rügen and Bornholm, there are similar beds, similarly situated.

The interglacial beds are best developed in Eastern and Western Prussia, where they are of greater thickness, and occupy greater areas than elsewhere. They include sand, peat, etc. Some of them are marine, while some are of fresh-water origin. They have yielded many fossils. The general facies of their molluscan faunas, both marine and fresh water, denotes a temperate climate. All the marine molluscs are North Sea forms, and still live in the Kattegat. Most of them are now living in the western Baltic. The testimony of the fossil land mammals confirms that of the molluscan faunas as to the temperate climate of the continent between successive glaciations.

Considered as a whole, the character of the "interglacial" fossil beds of Northern Europe is such as to indicate that if they belong to one epoch, that epoch must have been one of considerable length and complexity. Interglacial peat beds in Holstein sometimes alternate with sand, and contain floras which denote considerable changes of climate,

from cold to temperate and back again to cold. The mammalian remains likewise indicate fluctuations of climate. In Central Russia there are fossil beds overlying the drift of the most extensive ice sheet. These fossil beds are not buried by till, since they are beyond the limit of the later advance of the ice, but they are clearly neither post- nor pre-glacial. They are thought to represent a climate more humid and more mild than that which now exists in the same region.

Evidence for the existence of multiple ice epochs is not confined to the fossil beds, strong as their testimony is. In Germany there is an "upper" bowlder clay different in physical and lithological constitution from the "lower." This implies a difference in direction of movement of the ice which formed the two beds of till. Thus in Western Germany, the "lower" till was deposited by ice moving from north to south, while the "upper" till was deposited by ice moving from north of east to south of west. This two-fold division of the bowlder clay exists south of the region of the great Baltic ridge, though the southern limit of the "upper" till south of this ridge seems not to have been accurately determined.

As in Britain, so on the continent, Professor Geikie finds evidence that the ice-sheet which reached farthest south, and which deposited the "lower" till of Western Germany, is not the oldest ice-sheet which affected Northern Europe. In Southern Sweden there is a till or ground moraine older than that produced by the most extensive ice-sheet. This oldest bed of drift, so it is affirmed, was deposited by ice moving from the southeast to the northwest. The overlying drift is the product of ice which moved from north-northeast to south-southwest, or nearly at right angles to the direction of the first movement. No interglacial beds are found here, but the diversity of movement is so great that, taken in connection with the extraordinary direction of the first, its significance cannot be trifling. It is to be noted that the foregoing interpretation does not involve three periods of drift deposition in Southern Sweden. The "lowest" ground moraine is referred to the first epoch (the time equivalent of the Weybourn crag), while the "upper" must be made to include the deposits of the second and third, if deposits of both exist. Some corroborative evidence of a great "Baltic" glacier, which antedated the most extensive *mer de glace* of the continent and of Britain, is thought to be found in certain fossil beds of Central Germany, though for their own particular region these fossil beds are thought to be pre-glacial. The "lower" till of Central Ger-

many is correlated with the "lower" till of Britain (second glacial, but first Pleistocene glacial epoch). The "upper" till of Central Germany (south of the Baltic ridge) is separated from the "lower" by beds containing the remains of a temperate fauna and flora. For the distinctness of the epochs of these two sheets of drift, the evidence is certainly strong. The "upper" till is correlated with the drift of the second Pleistocene *mer de glace* of Britain.

The great Baltic ridge of North Germany is regarded as a huge terminal moraine, on the outer part of which are the *End-moräne* or *Geschiebewälle* of the Germans. This moraine is looked upon as the southern margin of a sheet of drift which overlies the "upper" till of Central Germany. Some of the fossil beds of North Germany are believed to lie between this third sheet of drift and the second, the second being the equivalent of the "upper" till of the region south of the Baltic ridge.

The "lower" till of Schleswig within the Baltic ridge, is thought to correspond with the "upper" till of Middle and Western Germany. This implies that the direction of movement during the time of the great Baltic glacier, was notably different from that during the production of the "upper" till of Middle Germany. Furthermore, the so-called "lower" till of Schleswig is known to be underlain by a still lower till separated from it by fossil beds indicating a temperate climate. It is therefore concluded that the till of Schleswig is referable to three distinct epochs. The basis for the reference of the drift sheet limited on the south by the Baltic ridge to a separate epoch — the fourth — is threefold: (1) The fossil beds between it and the next lower drift-sheet; (2) the change of level which these fossil beds imply; and (3) the differences in direction of movement. The drift which is limited by the Baltic ridge in Germany is correlated with the epoch of the "district" glaciers in Scotland.

Evidence for a fifth glacial epoch, that is, an epoch later than that of the great Baltic glacier, has not heretofore been recognized in Scandinavia. The mountain valley moraines of that peninsula have been regarded as moraines of recession. From this conclusion Professor Geikie is inclined to dissent. He is disposed to think that these moraines may represent a minor ice epoch or ice epochs, corresponding with the latest epochs of Scotland.

It is interesting to note, though too much weight must not be attached to the analogy, that the outermost border of the drift in

Europe, as in America, is not characterized by terminal moraines; that the limit of the drift deposited during the second advance of the ice in Europe, as in America, is not commonly marked by well-defined moraines, though moraines are not altogether wanting; that the great body of loess in Europe, as in America, seems to be connected with the ice advance which succeeded the greatest; and that the ice during the next succeeding advance (the second after the greatest), both in Europe and America, developed the great terminal moraines, and that these terminal moraines are bordered on the outside by plains and valley trains of sand and gravel, denoting more vigorous drainage than during the earlier stages of the ice.

A chapter is devoted to the glaciers of Middle Europe. Nearly all the mountains of this part of Europe had their glaciers during one or more of the glacial epochs. In some of these regions, as in the Vosges Mountains of Alsace, there is more or less evidence of separate epochs with inter-current non-glacial conditions.

In Switzerland details concerning the glacial formations have been worked out in great detail by several geologists, among them Messrs. Penck, Brückner, Böhm, and Du Pasquier. Much of the work in Switzerland has been done independently, but the conclusions reached appear to be nearly the same in whatever part of the Alpine country the areas investigated lie. Three thoroughly distinct series of glacial deposits are recognized, separated by interglacial beds representing genial climatic conditions. The intervals between the successive glaciations were long, perhaps longer than the time since the last. This evidence is not confined entirely to the regions which were actually covered by the ice. It is also found in territory which ice did not cover. The evidence outside the areas actually glaciated is drawn from three series of gravel deposits. The oldest series of gravels, which Professor Geikie calls the "plateau" gravels, were deposited during the first recognized epoch of glaciation in the Alps. After the deposition of these gravels there was a long period of erosion. Streams cut deep and broad valleys through these gravels, and into the rock upon which they rest. During this erosion interval the Inn, for example, deepened its valley several hundred feet.

In the valleys thus formed, a later deposit of glacier gravel was made. This gravel constitutes the so-called "high terraces." There is direct evidence that this gravel was connected in time and origin with the second glacial epoch of the Alpine region. Subsequent to the deposi-

tion of this second series of gravels, there was a long period of erosion and weathering, during which deep valleys were cut in the high terrace gravels. This period of erosion corresponds with the second interglacial epoch of the region. Later, a third series of glacial gravels was deposited in the valleys cut out of the second series. This third series may be traced into direct connection with the terminal moraines in the mountain valleys. The foregoing sequence was first established by Penck for Upper Bavaria, but it has been found to hold for all the Alpine *Vorland* between the Rhine and the Traun. By Professor Geikie these three glacial epochs of Switzerland are believed to correspond to the first three glacial epochs of Northern Europe.

The argument for the tripartite division of the glacial deposits of Switzerland as stated by Professor Geikie, seems strong. The evidence has been gathered with great care by those on whose conclusions we have learned to rely. Until it is decided how far the ice must have retreated, relative to earlier and later advances, and how long it must have stayed in retreat, in order that a re-advance shall constitute a new ice epoch, there is of course chance for discussion as to whether these separate series of glacial deposits represent distinct glacial epochs. But from Professor Geikie's exposition, there can hardly be a doubt that the three subdivisions of the Alpine drift are thoroughly distinct, distinct enough to make their reference to separate epochs the most natural method of classifying them.

Later than the three glacial epochs, as determined by Penck and his associates, there are said to be two later sets of moraines in Switzerland. To these Professor Penck assigns a "post-glacial" age. Geikie thinks they may belong to the fourth and fifth epochs, according to his general classification for the whole of Europe. This would make five glacial epochs in Switzerland, according to Geikie, two of which are "post-glacial," according to Penck.

Evidence of the same general import is likewise found in the Auvergne. It will thus be seen that the evidence for the existence of multiple glacial epochs is not confined to one area, or even to a few closely associated areas. The evidence is drawn from widely separated sources, and is found in all regions which were extensively affected by glaciation.

Concerning the general question of the division of the glacial period into epochs, it may be said that too much reliance is not to be placed on specific bits of evidence, or on specific lines of evidence.

Specific bits of evidence, or even whole lines of evidence, which are cited in support of separate epochs, might be interpreted in some other way. But in dealing with such questions we have always to remember that several lines of evidence, no one of which is absolutely conclusive, may together be so strong as to carry conviction. The question is not whether this or that bit or line of evidence *might be* explained in some other way than by the theory of distinct glacial epochs, but whether, as a matter of fact, the aggregate of evidence compels the adoption of this theory. The question is not *what might have been*, but *what was.*

According to Professor Geikie the sequence of events during the prolonged glacial period is as follows: (1) A glacial epoch, preceded by a period of increasing cold. At this time ice filled the basin of the Baltic. The Alpine lands were swathed in snow and ice, and great glaciers came out from the mountains, making moraines on the low ground at their bases. The mountain regions of Britain were probably ice-clad, though of this there is no direct evidence. In France there were glaciers from the volcanic cones of Auvergne and Cantal, which descended so as to deploy upon the plateaus. (2) Then followed the first interglacial epoch. The southern part of the North Sea became land, and a temperate flora, comparable to that of England today, covered corresponding latitudes. A luxuriant deciduous flora occupied the valleys of the Alps, and flourished at heights which it no longer reaches. (3) The first interglacial epoch was succeeded by a second glacial epoch. During this time the northern *mer de glace* reached its greatest extent. At the same time, the Alpine glaciers reached their greatest extension, while in the other mountains of Europe snow fields and glaciers came into existence. (4) The dissolution of this ice sheet was followed by a second interglacial epoch. The climate of Northern and Central Europe again became temperate, a temperate flora and fauna finally replacing the arctic forms which first tenanted the land after the ice disappeared. The plants which occupied Germany and the central plains of Russia indicate a less extreme climate than is now experienced in these regions. Later, the climate became more rigorous. The amount of erosion accomplished during this second interglacial interval was such as to testify to its great duration. (5) A less extensive, but still great ice sheet overwhelmed a large part of the British Islands, and spread itself widely upon the continent. As in the preceding epoch the Scandinavian and British

ice sheets were confluent. From the Alps great glaciers descended to the lowlands. (6) Eventually the ice of the third epoch disappeared and temperate conditions succeeded. Of this change the best evidence is furnished by the younger interglacial beds of the Baltic coast-lands. (7) The fourth glacial epoch succeeded the third interglacial. During this epoch the Lowlands of Scotland were submerged to a depth of 100 feet. The Highlands of Scotland had their glaciers, which in places reached the sea. The Alpine glaciers flowed for long distances down the great valleys, but fell far short of the dimensions reached by those of the earlier epochs. From Scandinavia, the ice moved south to the Baltic ridge in Germany. (8) Following the fourth glacial epoch there was a fourth interglacial epoch, when deciduous trees spread far north into regions where such trees no longer flourish. The Baltic was converted into a great lake. Submergence followed, and the Baltic became an arm of the sea, with a fauna indicative of a warmer climate than the present. (9) During the fifth glacial epoch there were local valley glaciers in the British Isles, the position of which shows that the snow line in Scotland had an average height of 2500 feet. During this epoch Scotland was submerged to an extent of about fifty feet. In the Alps, the fifth glacial epoch is marked by moraines of the second so-called "post-glacial" stage. (10) The fifth interglacial epoch was marked by the re-emergence of the land and the retreat of the valley glaciers. Britain's area became wider than at present, but it is not known that connection was made with the continent. (11) During the sixth glacial epoch Scotland was submerged twenty or thirty feet more than at present. The snow line then stood at an elevation of something like 3500 feet in Scotland, and a few small glaciers existed in the lofty mountains. It is to be noted throughout, that elevation and amelioration of climate go together, while colder conditions accompany subsidence.

Concerning the origin of the loess Professor Geikie takes no uncertain ground. He believes that it was primarily an aqueous deposit, made during the closing stages of more than one glacial epoch, but that the principal body of it was connected with the closing stages of the third epoch. Subsequent to its first deposition, it is held that the wind shifted it from the position in which it was left by the water, on a somewhat extensive scale. The fossils of the loess seem to indicate that an arctic fauna was succeeded by a sub-arctic, and this in turn by a temperate one.

In his chapter on extra-European countries, our author recounts evidence to the effect that there were extensive glaciers in most of the mountain ranges of Asia during the glacial period. At this time glaciers are believed to have been much more extensive than now, in regions where they now exist, and to have existed in many places where they are not now found. The glacial deposits of Asia have been little studied, and have not thus far yielded evidence of recurrent epochs. In Africa there is evidence that there were somewhat extensive glaciers in the Atlas Mountains, where there are said to be large moraines at an elevation of not more than 6000 feet. There is evidence, too, that glaciers descended much lower than at present from some of the mountains near the equator. Thus about Mt. Kenia (18,370 feet) glaciers have at some time descended between 5000 and 6000 feet lower than at the present time. In South Africa, likewise, there are traces of glaciers in the mountains at elevations ranging from 1000 to 5000 feet. In the Australian Alps, glaciers are found to have descended to a level little more than 3000 feet above the sea. There is evidence also of glaciation at points in South Australia. Within this province the effects of ice action are observable down to within forty feet of the sea level about St. Vincent Gulf, latitude 35° south. There are also evidences of former glaciers in Tasmania, and the ice in New Zealand is known to have been much more extensive at some earlier time than now. Kerguelen Island, it is believed, has at some time been completely smothered by ice. In South America, too, glaciers were formerly much more extensive than now.

Professor Geikie makes no specific statement looking to the time correlation of the glacial conditions in these various countries with those of Europe and North America, but the implication, perhaps unintentional, is that they fall within the limit of the glacial period of those countries. Until the cause of the glacial period is known, it would seem to be unfortunate to assume that the glaciation of different continents was synchronous.

The chapters devoted to the drift of North America are more than a summary of the drift phenomena of our continent. They are written from the standpoint of Pleistocene history and embody new suggestions on many points.

Professor Chamberlin calls attention to the fact that the known history of glaciation practically begins with the time when the ice reached its outermost limit. The earlier glacial history is largely lost, and that

which is not altogether lost, is greatly obscured. A distinct innovation is suggested in the chronological classification of the drift. Instead of referring to a given drift deposit as belonging to the first, second, or third glacial epoch or episode, it is proposed to designate the deposits made during the more distinctly marked stages of the glacial period, by the names of type localities. Thus it is proposed to apply the name *Kansan* to the deposits made by the most extensive sheet of ice. This formation is now uncovered only along the southern border of the drift. As now exposed, it finds extensive development in Kansas, Missouri, Illinois, Iowa, Nebraska, and Dakota, and lesser development in several other states. In general, this formation is thin at its outer edge, its terminus not being marked by morainic accumulations. It has suffered much erosion. In many regions, remnants only have escaped destruction at the hands of erosive agencies. The rock surface underlying the exposed part of this formation was in general little modified by the ice.

The Kansan formation is overlapped by another sheet of drift, the *East Iowan*, which encroached upon it from the north, leaving only its southern margin exposed. Between the two formations there is a widespread body of soil, which is in many places thick. It was probably as well developed as the soils of the present surface. It is known to extend fully fifty miles back from the outer border of the East Iowan formation. The plant remains which this soil contains have not been studied in great detail, but they are such as to indicate a temperate climate. The interval of deglaciation therefore was important. This interval of deglaciation is called the post-Kansan interval. Some estimate of its length is also based on the amount of erosion which the Kansan formation has suffered, compared with that which has affected the next succeeding formation.

Like the Kansan, the East Iowan formation was once widespread, but as a rule only that part of it which was not covered by later drift can now be certainly differentiated. Like its predecessor the East Iowan formation is not generally bordered by distinct terminal moraines. With the East Iowan formation, the main body of the loess seems to have been connected in time of origin.

Following the East Iowan formation, it would appear that there was an interval of deglaciation sufficiently long "to permit a notable change in the configuration and conditions of the land—the development of capacious valleys; the general carving of the surface into an erosion

topography; the production of vegetal beds and soils, and the deep penetration of weathering."

Following this period of deglaciation, the ice again advanced, making, and finally leaving, the body of drift which it is proposed to designate the *East Wisconsin* formation. As now exposed this formation is much more extensive than either of the preceding, though it is less extensive than either of the others were before they were buried and disturbed or destroyed by later incursions of the ice. It is characteristic of the East Wisconsin formation that it is bordered by great moraine loops. It is also characteristic of this formation that extensive gravel plains, in distinction from silt and loess plains, border its moraines on the outside. It is in connection with this formation that drumlins, kames, and osar are best developed. The East Wisconsin formation is by no means simple. During its development there were repeated oscillations of the ice edge. Some of them may have been considerable, but they are not believed to mark more than minor stages in the history of the glacial period.

At several closely associated points in the vicinity of Toronto there are fossil beds of stratified drift between beds of till. These fossil beds have yielded a rich flora and fauna, which have recently been studied by Messrs. Coleman, Townsend, and others. The character of the fossils is unequivocal. They indicate a climate milder than that of the present time in the same region. The molluscan fauna would be appropriate to Southern Illinois, the flora to Southern Ohio. Unfortunately, the position of the fossil bed in the great drift series is not certainly known. It is hardly probable that it belongs between the Kansan and the East Iowan formations. It is more probable that it lies between the East Iowan and the East Wisconsin formations. On the other hand, it may lie between the East Wisconsin formation, and the deposits of a later ice epoch which, within the United States, has not been differentiated from the preceding. If the fossil bed occupies the position last mentioned, there would be reason for separating the drift series into four principal formations, rather than three.

Professor Chamberlin is very conservative with reference to the chronological importance of the several subdivisions which he proposes. He does not assert that the three main subdivisions for which he proposes names, are of equal importance. It is left an open question which of the two deglaciation intervals between these formations is the more important. It is left an open question, so far as

affirmation is concerned, whether either one or both of these intervals is of sufficient importance to constitute the succeeding ice advance a separate glacial epoch. It is clear, however, from the discussion, that the author believes in at least a bi-fold division of the glacial formations of sufficient importance to allow each to be assigned to a separate epoch. It is also clear that he is hospitable to a threefold division each with the rank of an epoch, and the way is left open for recognition of a fourth.

In this connection Professor Chamberlin makes some suggestions of general interest concerning the subdivisions of the drift. He says:

"If the ice age consisted of distinct glaciations separated by climatic conditions as genial as those of today, they might as properly be called periods as epochs of glaciation. If the intervals of ice retreat, whether they amounted to complete disappearances or not, were comparable to the post-glacial period in duration, in the amount of erosion, weathering, soil production, vegetal accumulation, orographic movement, or other work done, or in the geniality of their climate or the character of their life, they are surely entitled to be recognized as marking epochs. If the intervals fall notably short of this, it is doubtless best to regard them as marking episodes, rather than epochs. The need for recognizing them would still remain, however, if we are to decipher and delineate the intimate history of the Ice Age."

We suspect that many glacialists would not be willing to follow the above suggestion in full. We suspect that many of them would hold that an interval of deglaciation might fall "notably" short of the post-glacial interval, and still the re-advance of the ice constitute a separate glacial epoch, especially if the retreat and the subsequent re-advance of the ice were very considerable. If, for example, the ice retreated so far from its extreme position as to free the territory of the United States, and if, during this retreat, the region freed became temperate, a subsequent advance of the ice to the limit of the East Iowan formation might perhaps not improperly be regarded as a distinct glacial epoch, even if the deglaciation interval were notably shorter than the post-glacial epoch. Especially would this be true, if the ice remained long in retreat, and if other events, such as changes of continental attitude, intervened. Even on the basis which Professor Chamberlin has proposed, there is in the minds of many geologists no doubt but that at least two, and very likely three distinct glacial epochs have affected the North American continent.

Professor Chamberlin very properly insists that just at present it is a matter of subordinate importance whether the several divisions of the ice period be called epochs or episodes; that the thing which is impor-

tant is the recognition of the complexity and the protracted character of the glacial period as a whole. Until this is recognized, it will be difficult to prosecute work intelligently along the lines which must ultimately determine whether the rank of the several subdivisions is epochal or episodal.

A single word may be added with reference to Professor Geikie's chapter concerning the "Cause of the Glacial Climate." It has already been noted that the discussion of this subject has been relegated to the last chapter of the volume. In the course of this discussion it is evident that Professor Geikie holds much less strongly than heretofore to Croll's hypothesis of glacial climate. While he indicates that this hypothesis probably "contains a large element of truth" he does not regard it as a full solution of the vexed question. He further indicates that the complex phenomena of Europe "are evidence of a succession of changes too manifold, and perhaps occupying too short a space of time, to be accounted for by the cause to which Croll appealed." Professor Geikie's attitude seems to be well expressed in one of his closing sentences: "The primary cause of those remarkable changes is thus an extremely perplexing question, and it must be confessed that a complete solution of the problem has not yet been found."

ROLLIN D. SALISBURY.

Papers and Notes on the Glacial Geology of Great Britain and Ireland. By the late HENRY CARVILL LEWIS. Edited from his unpublished MSS., with an introduction, by HENRY W. CROSSKEY. Pp. lxxxi+469. Maps x., figures 83. London: Longmans, Green & Co., 1894.

Dr. Crosskey and the devoted wife of the late Professor Henry Carvill Lewis have placed all who are interested in glacial phenomena under lasting obligations by the publication, in elegant form, of the papers and notes of one who was among the most active and enthusiastic of American glacialists. It would have been a pleasure to the writer to have made earlier notice of this work, had not his absence from the country prevented. The book embraces papers on (1) Comparative Studies upon the Glaciation of North America, Great Britain and Ireland; (2) The Terminal Moraines of the Great Glaciers of England; (3) On some Important Extra-Morainic Lakes in Central England, North America, and elsewhere, during the period of maxi-